Levels of abstraction in BP models

**Process Map**
- Stakeholders: Chief Executive, Management etc.

**Business Process**
- Stakeholders: Process Responsible, Process Manager, Business Process Expert etc.

**Workflow ("Macro Flow")**
- Stakeholders: IT Specialist, System Architect, Application Developer etc.

**Micro Flow**
- Stakeholders: Application Developer, Programmer etc.

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Views on BP models

- Functional View
  - Activity
  - Sub process

- Dynamic View
  - Control Flow
  - Information Flow

- Organizational View
  - Actor
  - Resource

- Business Process Model
  - Product
  - Artefact
  - Content View
  - Times & Costs
  - Probabilities & Stat. Distributions

- Quantitative View
  - Version
  - Variant

- Time-oriented View

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Information mining from the model pool -- models constitute "know-how" for a company, so we want to query them and use them with:

- **Queries**
  - Ad-hoc queries
  - Pre-defined queries (project/department/company specific)
  - Information preparation for target groups (focus on the subject)

- **Consistency checks**
  - State of modeling
  - Existence of objects
  - Quality of models (modeling guidelines)
Static Analysis: Scenaria

- **Evaluation of simulation results**
  - Generating non-standard simulation results, e.g., "Determine all processes which have a cycle time greater than 5 days"
  - Connecting static and dynamic model information, e.g., "Determine activities that occur in processes with cycle time >5 days"
Query languages

- **Table-based -- SQL**
  - SQL standard
  - Declarative language, many available tools
- **Graph-based -- OQL**
  - OQL -- based on graph theory
  - OQL is a standard for OODBMS
  - Navigating and declaring access
  - Operates on labelled, directed trees/graphs, works well for complex structures
  - No full implementation of OQL yet
Query languages

• Query-by-Example
  • Dialog- or editor-supported
  • No standard, tool-dependent (but some common features...)
  • Queries formulated through powerful front-end
  • User needs no knowledge of the actual query language
Granularity of queries

- **Attribute Level**
  - Query on object properties
  - "Give me the execution time of activity 'risk check'"

- **Object/Class level**
  - Number of objects that satisfy a property
  - "Find all activities with execution time > 1h."
  - "Find all instances of class document."

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Granularity of queries

- **Model** level
  - Explore one or a few models
  - "Which activities are needed for processing a credit application?"

- **System** Level
  - Queries over all the models
  - "Find all business processes that require manual activity."
Information aggregation

• Table-oriented
  • View query results in table-oriented form
  • Most users are familiar with this representation (Excel spreadsheets)

• Graphical
  • Good representation of quantity-oriented results (pie charts, bar charts)
  • Intuitive representation of different result sets

• Relation-/Dependency Graph
  • Representation of dependencies in query result
  • Visualization of complex model structures (Part-of, model dependencies)
  • Generation of model-spanning views (process hierarchies, role-activity-diagrams)
The ADONIS Query Language (AQL) is an adaptation of OQL.

In ADONIS, you can choose a query from a library of queries, or define your own using AQL.
1. All activities

AQL expr: `<"Activity">`

2. All things that belong to the section “Distribution”

AQL expr: `{"Distribution"}<-“belongs to”`

2a. All employees who belong to the section “Distribution”

AQL expr: `{"Distribution"}<-“belongs to” and `<"Employee">`

3. All employees with the role Specialist

AQL expr: `{"Specialist"}<-“has role” and `<"Employee">`
4. All employees that have the role Specialist and belong to the organizational unit "Section".

AQL expression:

\[
\text{AQL expression:}\]

\[
\{\text{"Specialist"}\} \leftarrow \text{"has role"} \\
\text{and } \langle \text{"Employee"} \rangle \text{ and} \\
\{\text{"Section"}\} \leftarrow \text{"belongs to"}
\]

\[
\langle \text{"Employee"}\rangle[\text{?"has role"} \rightarrow \{\text{"Specialist"}\}] \\
\text{and } \{\text{"Section"}\} \leftarrow \text{"belongs to"}
\]

5. All activities with execution time greater than five minutes.

AQL expression:

\[
\langle \text{"Activity"}\rangle[\text{?"execution time" } > \text{"00:00:00:05:00"}]
\]
Predefined Queries

1. Choose a query
2. Complete the query
3. Evaluate the query

Example from the ADONIS standard application library
The representation of results of object attributes in lines in the ADONIS browser can only be displayed in 5 columns:

- **Model** (= Model name)
- **Name** (= Object name)
- **Class** (= Class name)
- **Attribute** (= Attribute name)
- **Value** (= Attribute value)
Building a User-Defined Query

1. Select a standardized query
2. Add the standardized query
3. Insert a connection operator
4. Select another standardized query
5. Add the standardized query ...
6. Evaluate the query

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Dynamic Analysis: Scenaria

- **Determine volume-, time- and cost-dependent results**
  - Quantitative evaluations of process models.
  - Find critical and dead-end process paths.
  - Budget- and cost center-planning.
- **Resource planning and capacity management**
  - Evaluation of business processes in relation to stakeholders, roles, organizational units, positions etc.
  - Determination of process cycle times relative to committed resources and actors.
  - Calculation of manpower requirements.
Dynamic Analysis: Scenaria

- Optimization of business processes and working environments
  - Comparison of as-is and to-be business processes
  - Identification of technical and organizational opportunities for optimization
  - Animation of process execution
What are we measuring?

- **Elapsed time** - clock time, e.g., if a process has two concurrent activities A1, A2 each of which requires 3mins, elapsed time for the execution of the process is 3mins, NOT 6mins

- **Execution time** - length of elapsed time it takes to execute all activities of the process without any waiting

- **Resting time** - length of elapsed time a process waits in-between activities

- **Waiting time** - length of time a process waits to get started

- **Cycle time** = Execution + Resting + Waiting
Approximate Dynamic Analysis: Pros

- Process structure need not be acquired
  - The acquisition of activity sequences and the control flow is not needed
  - Existing information, such as activity lists, serve as input for evaluation and analysis ("smooth transition")
- Capacity analysis
  - Despite small acquisition effort, necessary capacity can be determined
  - Analysis can be conducted with standard software (e.g., Excel)
- Analysis can be done manually, or with simple software tools
  - Quantitative data as basis for further analysis
  - If the process model is enriched with control structures, existing data can be re-used
Approximate Dynamic Analysis: Cons

- Process cycle time (execution time + waiting time) can't be calculated
  - Because of missing process structures
- Activity dependencies are not considered
  - Dependencies in the control flow of the business processes as well as cycles or concurrency are not considered in the evaluation
- No dynamic resource planning
  - Resource and capacity planning based on dynamically calculated waiting times is not possible
Example - Process Quantity only

Process "Change Name of Insurance Holder"
(Quantity: 1000)

- Search for customer in customer database
  - ET: 2 Min
  - Costs: 10 Units/Min

- Enter new name into database
  - ET: 1 Min
  - Costs: 10 Units/Min

- Print and send insurance policy
  - ET: 3 Min
  - Costs: 10 Units/Min

Time base: 8 h/day, 200 days/year
Process "Change Name of Insurance Holder"
(Quantity: 1000)

- Search for customer in customer database
  - ET: 2 Min
  - Costs: 10 Units/Min
  - Quantity: 1000

- Enter new name into database
  - ET: 1 Min
  - Costs: 10 Units/Min
  - Quantity: 800

- Print and send insurance policy
  - ET: 3 Min
  - Costs: 10 Units/Min
  - Quantity: 800
Example

<table>
<thead>
<tr>
<th>Business Process</th>
<th>Quantity</th>
<th>Execution Time</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change Name of Insurance Holder</td>
<td>1000</td>
<td>52000</td>
<td>60000</td>
</tr>
</tbody>
</table>

Activities

- Search for customer in customer database: 2 Min, 10 Units/Min
- Enter new name into database: 1 Min, 10 Units/Min
- Print and send insurance policy: 3 Min, 10 Units/Min

<table>
<thead>
<tr>
<th>Business Process</th>
<th>Quantity</th>
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<tr>
<td>Change Name of Insurance Holder</td>
<td>1000</td>
<td>52000</td>
<td>60000</td>
</tr>
</tbody>
</table>

Activities

- Search for customer in customer database: 1000 x 2 Min, 10 Units/Min
- Enter new name into database: 800 x 1 Min, 10 Units/Min
- Print and send insurance policy: 800 x 3 Min, 10 Units/Min
Example calculation

- **With process quantities**
  - All activities do have the same frequency
  - Total ET: \(1000 \times (2 + 1 + 3) \text{ Min} = 6000 \text{ Min}\)
  - Total Costs: \(1000 \times (2 \times 10 + 1 \times 10 + 3 \times 10) \text{ Units} = 60000 \text{ Units}\)
  - Workforce requirements: Total ET / 60 Min / 8 h = 12.5 Days
Example calculation

• **With process and activity quantities**
  
  • If information acquisition was done consistently, the process structure can be (partly) derived from table
  
  • Total ET: $1000 \times 2 + 800 \times 1 + 800 \times 3 \text{ Min} = 5200 \text{ Min}$
  
  • Total Costs: $10 \times (1000 \times 2 + 800 \times 1 + 800 \times 3) \text{ Units} = 52000 \text{ Units}$
  
  • Workforce requirements: Total ET / 60 Min / 8 h = 10.8 Days
Dyn Analysis with Structure: Pros

- Process cycle time can be calculated
  - Because of the available process structure
- Stability of calculated results
  - If the calculation is repeated without changing the input parameter, identical results will be derived (no statistical variations)
- Very efficient for certain classes of processes
  - If process flow has no/few concurrencies and cycles, calculations are very fast because they are numerical (no inference or simulation)
Dyn Analysis with Structure: Cons

• Not applicable for complex process models
  • If the process model contains complex control flows (many concurrency and decision points), the model cannot be evaluated analytically in acceptable time (exponential explosion of paths!)

• Acquisition of transition probabilities
  • The determination of correct transition probabilities for decisions / parallelities is sometime impossible or at least very time consuming

• No consideration of dependent probabilities
  • If probabilities in the process flow depend from each other ("agent-broker-problem"), the algorithmic calculation can lead to inconsistencies in the results (cycle time etc.)
Examples

BP without cycles

BP with cycles
Path Analysis

- **BP without cycles**
  - Calculate probabilities and parameters (time, cost) for each path
  - Sum up weighted paths $\Sigma(path \times probability)$

- **BP with cycles**
  - Calculation formula for case “without cycles” is not applicable
  - Use geometric series for $p < 1$:
  - Build geometric series for each cycle, then sum up each result of geometric series
  - For the example of the previous slide
    - Total = Result(C1) + Result(C2)
Example of Path Analysis

Path 1 = A1
Path 2 = A2 + A1

Cycle 1 = \text{path1} + 0.2*\text{path2} + (0.2)^2*\text{path2} + ...
\quad = -A2 + \text{path2} + 0.2*\text{path2} + (0.2)^2*\text{path2} + ...
\quad = -A2 + (1/(1-0.2))*\text{path2}

Cycle 2 = 0.8*(\text{path3} + 0.6*\text{path3} + + (0.6)^2*\text{path3} + ...
\quad = 0.8*(1/(1-0.6))*\text{path3}
No cycles: possible algorithm

Find all possible paths, calculate their probabilities and costs/times

\[ P_1 = 0.1 \times 0.3 \times (A_1 + A_2 + A_5 + A_6 + A_3 + A_4) \]

\[ P_2 = 0.1 \times 0.7 \times (A_1 + A_2 + A_5 + A_3 + A_4) \]

\[ P_3 = 0.9 \times (A_1 + A_2 + A_3 + A_4) \]

\[ \text{Total} = P_1 + P_2 + P_3 \]

Problem: Number of paths depends exponentially on the number of decision points...
More efficient algorithm

Now we consider every path segment

→ Path1 = A1 + A2
→ Path2 = A3 + A4
→ Path3 = A5
→ Path4 = A6 + A3 + A4
→ Total = Path1 + 0.9 * Path2 + 0.1 * (Path3 + 0.7 * Path2 + 0.3 * Path4)

This way, we don’t have to do the calculation on every possible path

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→ Path1 = A1
→ Path2 = A2 + A1
→ Path3 = A3 + A4

→ Total = \(-A2 + \frac{1}{1-0.2} \times \text{Path2} + 0.8 \times \frac{1}{1-0.6} \times \text{Path3} = -A2 + 1.25 \times \text{Path2} + 0.8 \times 2.5 \times \text{Path3}\)
Dependent Probabilities
Calculation with Dep. Probabilities

- Calculation without considering dependent probabilities

Without considering the dependent probabilities the business process has four paths:

Path 1: \((0.6 \times 0.6) \times [2 \text{min} + \max(1 \text{min} + 4 \text{min} ; 0 \text{min})] = 0.36 \times 7 \text{min} = 2.52 \text{ min}\)

Path 2: \((0.6 \times 0.4) \times [2 \text{min} + \max(1 \text{min} + 4 \text{min} ; 1 \text{min} + 3 \text{min})] = 0.24 \times 7 \text{min} = 1.68 \text{ min}\)

Path 3: \((0.4 \times 0.6) \times [2 \text{min} + \max(1 \text{min} + 1 \text{min} ; 0 \text{min})] = 0.24 \times 4 \text{min} = 0.96 \text{ min}\)

Path 4: \((0.4 \times 0.4) \times [2 \text{ min} + \max(1 \text{min} + 1 \text{min} ; 1 \text{min} + 3 \text{min})] = 0.16 \times 6 \text{min} = 0.96 \text{ min}\)

The average cycle time of the business process is:
\((2.52 \text{min} + 1.68 \text{min} + 0.96 \text{min} + 0.96 \text{min}) = 6.12 \text{ min}, \ \text{i.e. 6 minutes, 7.2 seconds}\)

- Calculation assuming dependent probabilities

Now the business process has two paths, i.e. "agent" case (path 1) and the "broker" case (path 2):

Path 1: \((0.6) \times [2 \text{min} + \max(1 \text{min} + 4 \text{min} ; 0 \text{min})] = 0.6 \times 7 \text{min} = 4.2 \text{ min}\)

Path 2: \((0.4) \times [2 \text{min} + \max(1 \text{min} + 1 \text{min} ; 1 \text{min} + 3 \text{min})] = 0.4 \times 6 \text{min} = 2.4 \text{ min}\)

The average cycle time of the business process is:
\((4.2 \text{ min} + 2.4 \text{ min}) = 6.6 \text{ min}, \ \text{i.e. 6 minutes, 36 seconds}\)
Workforce Requirements

• Many (re-) organization projects target on cost and cycle time reduction. In many companies with intensive usage of human resources, a cost reduction can (only/mainly) be reached by reducing personnel costs.

• For a business process, (abstract) workforce requirements can be calculated by considering the average execution time of a process and the number of times it is executed per year.

• If the execution time per business process can be divided and assigned to groups of actors participating in the process, (concrete) workforce requirements can be calculated, e.g. at the levels of organizational units, roles etc.
BP Simulation: Idea

- Do not analyze analytically the process
  - No calculations needed here!
- Simulate a run-through on the model
  - E.g., whenever a decision point is found, take a decision!
- The more runs, the more accurate the results
BP Simulation: Pros

- All models – even complex ones – can be evaluated
  - The models to be evaluated can contain complex control flows (concurrency and branches)
- Consideration of dependent probabilities
  - Dependent probabilities within a process are handled correctly ("agent-broker-problem"). Additionally, the "business correctness" of the problem is ensured
- Cycle time can be calculated
  - Since process structure is available
BP Simulation: Cons

- Results can vary
  - Because of stochastic distributions influencing the variables and transition conditions (acceptance!)
- Statistical knowledge, simulation basics may be missing
  - To apply simulation adequately, the user should have appropriate skills and statistical knowledge
Typical Simulation Parameters

Quantitative Parameter

Times
- Resting Time
- Execution Time
- Waiting Time
- Transport Time
- Cycle Time
...

Costs
- Activity Costs
- Actor Costs
- Process Costs
- Resource Costs
- Transaction Costs
...

Capacities
- Process Quantity
- Workforce Requirement
- Charge Rates
- Workload
- ...

Other Parameters
- Process Calendar
- Actor Calendar
- Resource Calendar
- Probabilities
- ...

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Path Analysis

- Simulation of processes without considering the working environment
  - Expected value of times and costs, cycle time
  - Critical paths / dead end paths
  - Determination of potential workforce requirement

\[ ?_0 \]
\[ ?_1 = ?_0 + ?_{1.1} \]

\[ ?_2 = ?_0 + ? \]
Capacity Analysis

- Simulation with assignment of activities to performers
- Exact determination of workforce requirement (capacity planning)
- Consideration of personnel costs

The algorithm assigns a performer

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Workload Analysis (steady state)

- Simulation including a queuing model for each performer
  - Activity and process costs
  - Capacity planning and workforce management based on process and performer calendars
  - Initialization phases
  - Simulates on timeline (in comparison to path and capacity analysis)
  - Dynamically calculated waiting times
Workload Analysis (fixed time)

- Simulation using queuing model
- Basic algorithm as for steady state
- Start/end of measurement user-defined
- Period-oriented results

<table>
<thead>
<tr>
<th>Process 1</th>
<th>Process 2</th>
<th>Process 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workload</td>
<td>Workload</td>
<td>Workload</td>
</tr>
<tr>
<td>Calculation Begin</td>
<td>Calculation End</td>
<td>Calculation End</td>
</tr>
</tbody>
</table>

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Understanding time

Company Time

Without considering weekends: waiting time: 1 day

Natural Time

Example:
1 activity - waiting time 1 day

With weekends factored in: waiting time: 1.4 days

Monday, Tuesday, Wednesday, Thursday: 80%, 1 day WT
Friday: 20%, 3 days WT
Calculation: 0.8*1+0.2*3=1.4

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Combining Analysis and Simulation

Abstraction Level

Analysis of To-Be Model

Simulation of As-Is Model

Simulation of To-Be Model

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